Clinical Decision Support Today & Tomorrow

What does the future have for us?

Mark Ansermino : University of British Columbia, Vancouver Canada

Potential conflict of interest

- Canadian Society of Anesthesiologists
- Michael Smith Foundation
- NSERC
- CIHR
- Research Draeger Medical
- Consultant GE Medical

Phases of *Innovation*

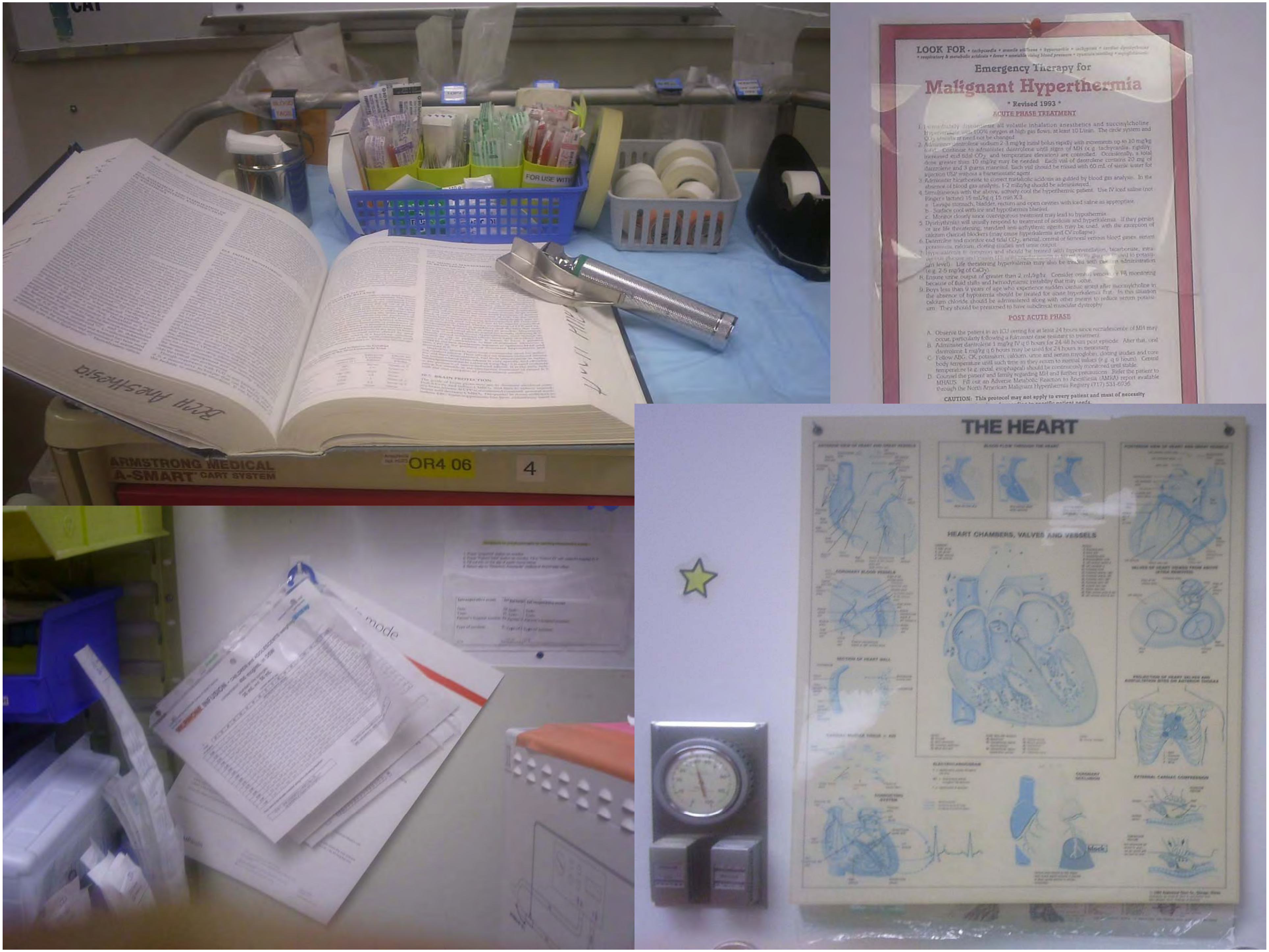
- It will never work
- It worked in animals but will never work in humans
- It worked in a small selected group of patients
- It worked in a large group but required special expertise or is too expensive
- Of course it works. I came up with the idea but did not bother to publish it.

Delivery of FastanII main backing store for the 418/III. Capacity 132MB.
London Hospital 1970

Who wants clinical decision support?

- Do you use clinical decision support?
- Do you want clinical decision support?
- Why do you want clinical decision support?

What is decision support?


ARMSTRONG MEDICAL
A-SMART CART SYSTEM
OR4 06
4
FOR USE WITH
Emergency Therapy for
Malignant Hyperthermia
* Revised 1993 *
ACUTE PHASE TREATMENT
POST ACUTE PHASE
THE HEART
HEART CHAMBERS, VALVES AND VESSELS

Clinical Decision Support

- **Clinical Decision Support** is a clinical system, document, application or process that helps health professionals make clinical decisions to enhance patient care.

Decision support in clinical monitoring

- Alerting
- Reminding
- Suggesting
- Critiquing
- Interpreting
- Diagnosing
- Predicting
- Doing!

What are we good at?

Your job is secure!

- Value judgments
- High complexity
- Adaptation to context
- High reliability
- Interdependence

What can we do better?

- **Cognitive bias**
- **Information overload**
- Changing habits
- Repetitive tasks
- Attention prioritization
- Multiple simultaneous tasks

Diagnostic Error

- 40 000 to 80 000 US hospital deaths result from misdiagnosis annually
- 9% TIA's missed
- 5% MI's missed

- Preoperative antibiotics

- These are NOT bad people…

Leape LL, Berwick DM, Bates DW. Counting deaths due to medical errors JAMA. 2002;288(19):2405

Newman-Toker DE Pronovost PJ. Diagnostic Errors - The Next Frontier for Patient Safety. JAMA. 2009;301(10):1060-1062

“The greatest obstacle to knowledge is not ignorance, it is the illusion of knowledge”

-

Daniel Boorstein

Adverse Anecdote

- Level IV evidence
- Last bad experience
- Expert opinion

Stuebe AM. The New England journal of medicine. 2011 Jul 7;365(1):8–9

Choice (Decision) Blindness

(Johansson, 2000)

Two Minds when making decisions

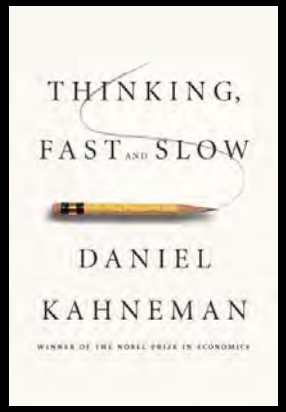
System 1
Intuition

Fast
Parallel
Automatic
Effortless
Associative
Emotional
Slow learning

System 2
Reasoning

Slow
Serial
Controlled
Effortful
Rule Governed
Neutral
Flexible

2X4



17X25

Heuristics and Biases

Heuristics are used to reduce mental effort in decision making, but they may lead to systematic **biases or errors in judgment.**

- Representativeness heuristic
  - insensitive to base rate/ prior probabilities
  - strong inference from small sample
  - confuse ‘normal’ and ‘rare’ events
- Availability heuristic
- Anchoring and adjustment
- Decision framing

Heuristics and Biases

Heuristics are used to reduce mental effort in decision making, but they may lead to systematic **biases or errors in judgment.**

- Representativeness heuristic
- Availability heuristic
  - swayed by information that is vivid, well-publicized, or recent
  - correlate events if close together
- Anchoring and adjustment
- Decision framing

Heuristics and Biases

Heuristics are used to reduce mental effort in decision making, but they may lead to systematic **biases or errors in judgment.**

- Representativeness heuristic
- Availability heuristic
- Anchoring and adjustment
  - depends on starting value
  - inadequate adjustment
- Decision framing

Heuristics and Biases

Heuristics are used to reduce mental effort in decision making, but they may lead to systematic **biases or errors in judgment.**

- Representativeness heuristic
- Availability heuristic
- Anchoring and adjustment
- Decision framing
  - prospect theory

Decision making is not rational?

Unrecognized limitations

The unrecognized limits of professional skill help explain why experts are often overconfident

> Statistical algorithms greatly outdo humans in noisy environments for two reasons: they are more likely than human judges to detect weakly valid cues and much more likely to maintain a modest level of accuracy by using such cues consistently.

Daniel Kahneman

Detecting changes – Real Time

Real time clinician compared to post hoc review

	PPV	Sensitivity	% Detected
HR	0.75	0.60	59.54
NIBPmean	0.60	0.63	63.33
SpO2	1.00	0.06	6.25
ETCO2	0.74	0.13	12.85
MVexp	0.55	0.11	11.17
RR(CO2)	1.00	0.01	0.94
TOTAL	0.64	0.10	9.54

PPV – positive predictive value

Ansermino, et al.. Anesthesia and Analgesia. 2009 ;108(3):873-80.

How do we make decisions?

Special Article

Defining rules for the identification of critical ventilatory events

[Définition de règles pour identifier les événements respiratoires critiques]

J. Mark Ansermino FRCPC, Maryam Dosani BSc, Erica Amari BA, Peter T. Choi MD FRCPC MSc, Stephan K. W. Schwarz MD PhD FRCPC

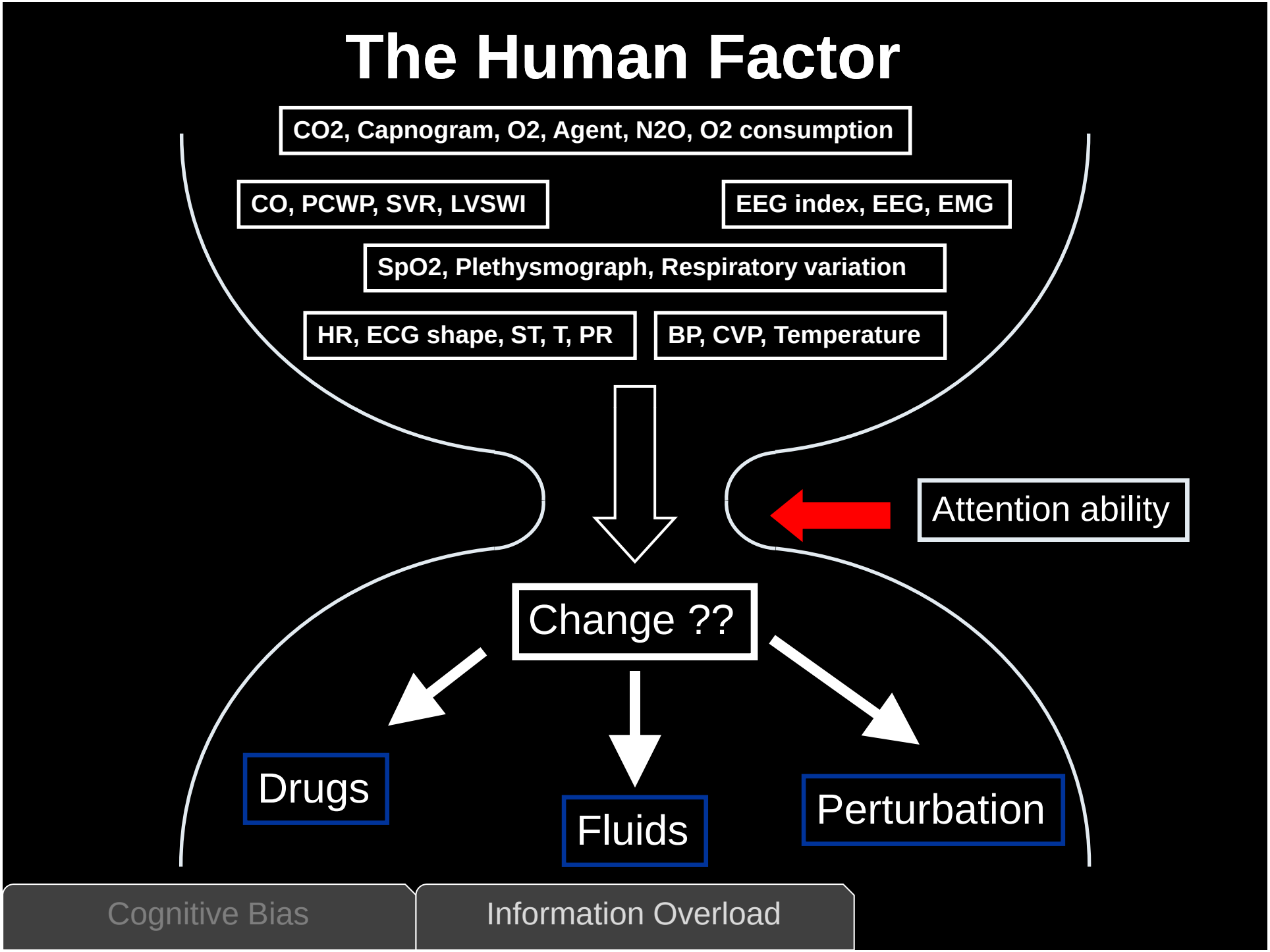
CAN J ANESTH 55: 10 www.cja-jca.org October, 2008

What has changed in healthcare?

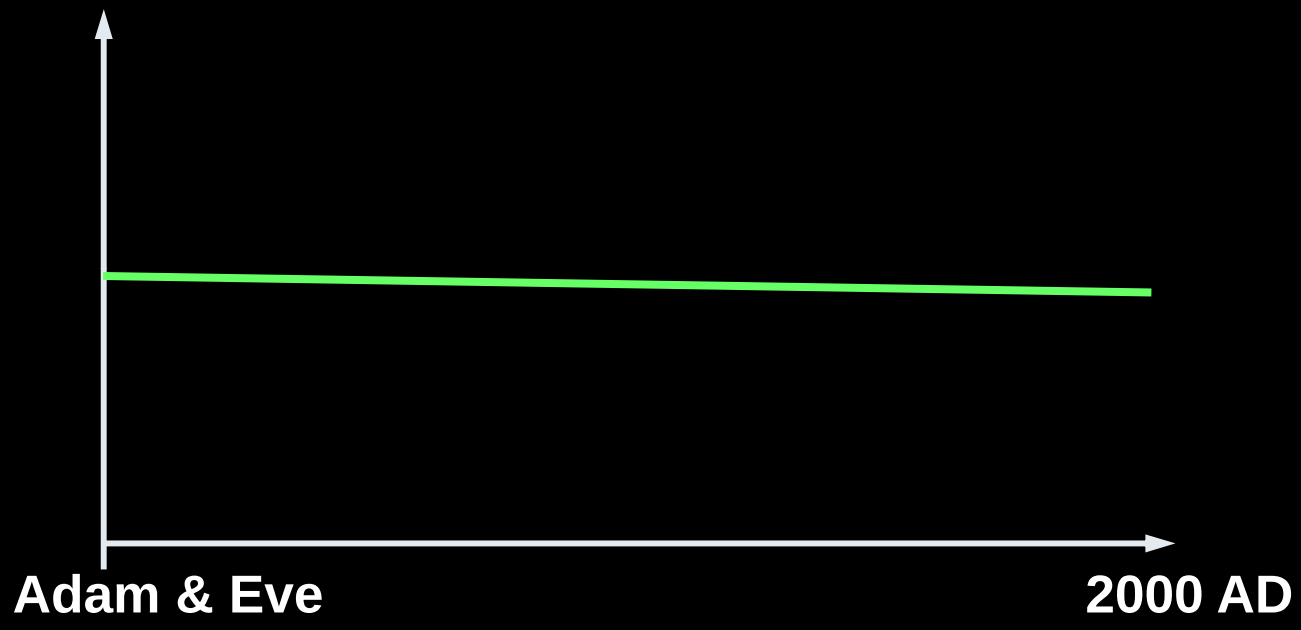
Information

What will change healthcare?

Cognitive Bias | Information Overload

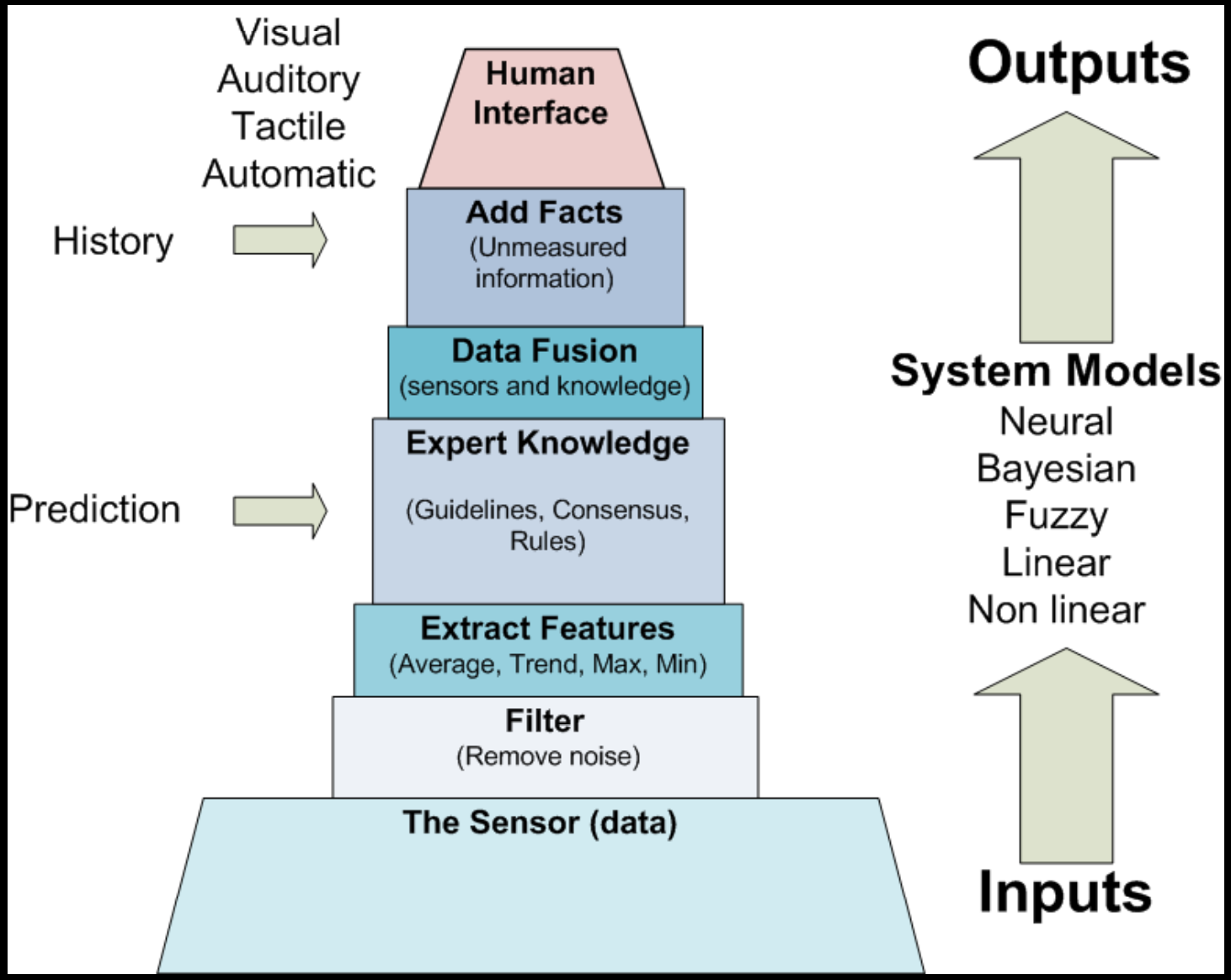

The Human Factor
CO2, Capnogram, O2, Agent, N2O, O2 consumption
CO, PCWP, SVR, LVSWI
EEG index, EEG, EMG
SpO2, Plethysmograph, Respiratory variation
HR, ECG shape, ST, T, PR
BP, CVP, Temperature
Attention ability
Change ??
Drugs
Fluids
Perturbation
Cognitive Bias
Information Overload

Human Vigilance Over Time

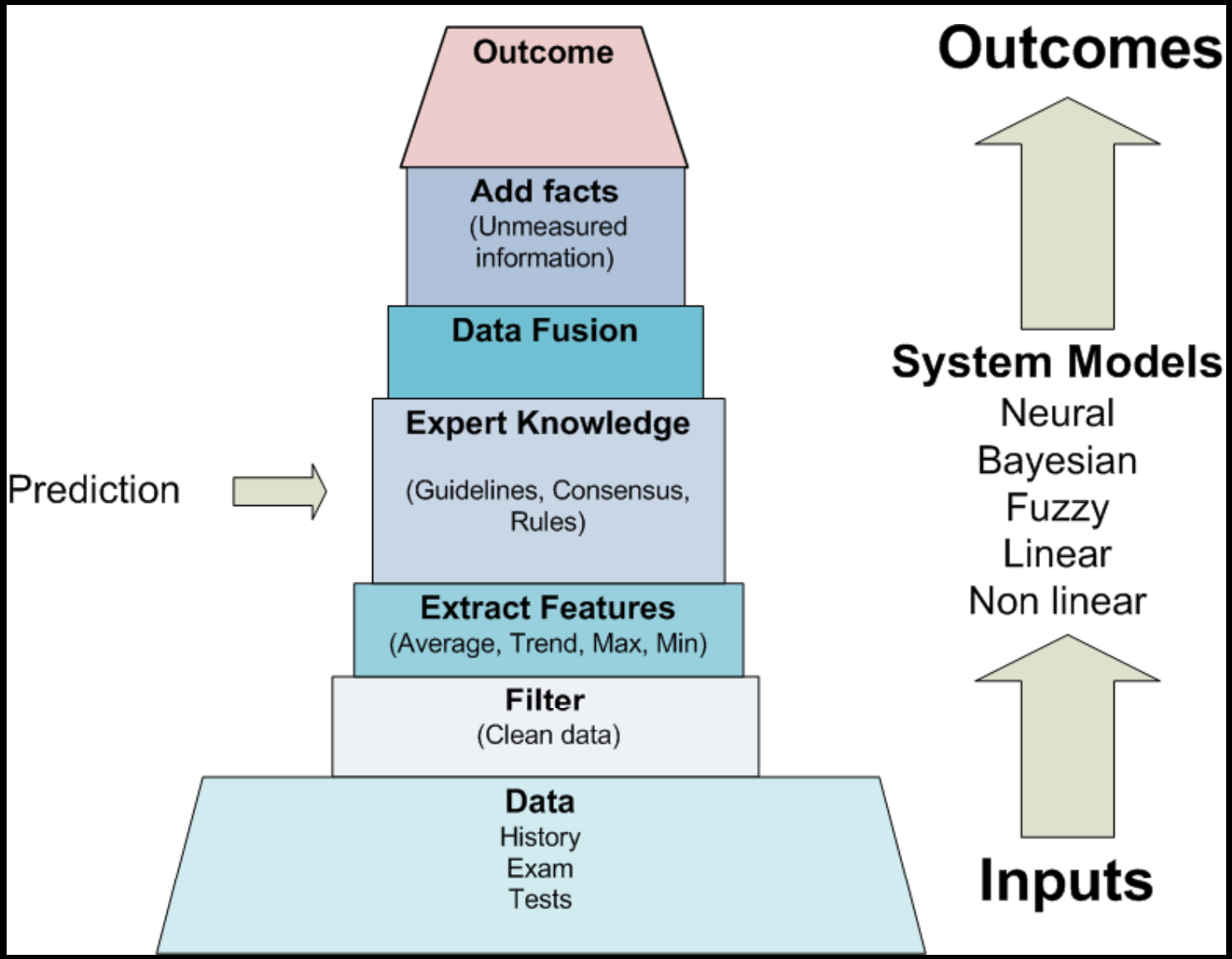


The most precious resource is human vigilance.

The Expert System (sensor)



The Expert System (outcome)



Cognitive Bias

Information Overload

Medicine Based Evidence

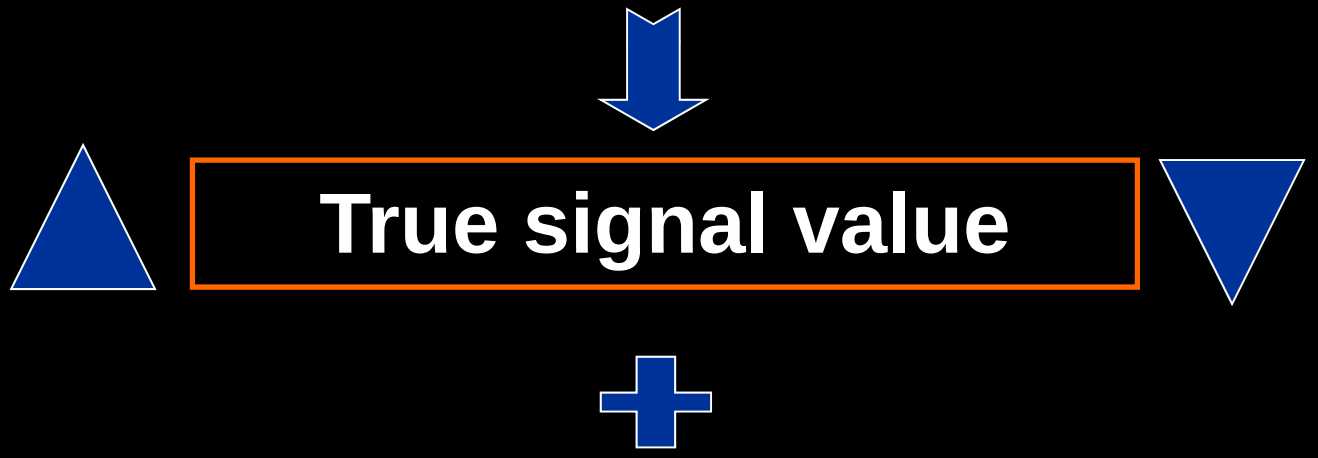
- ***Comparative Effectiveness Research***
  - clinically relevant issues
  - who and where were the patients
  - what and why were the treatments
  - when and how were the outcomes
  - assessment of validity and generalizability considered together and denoted as accuracy

Context Specific Monitoring

Look at the trend!!

Adaptive feature extraction

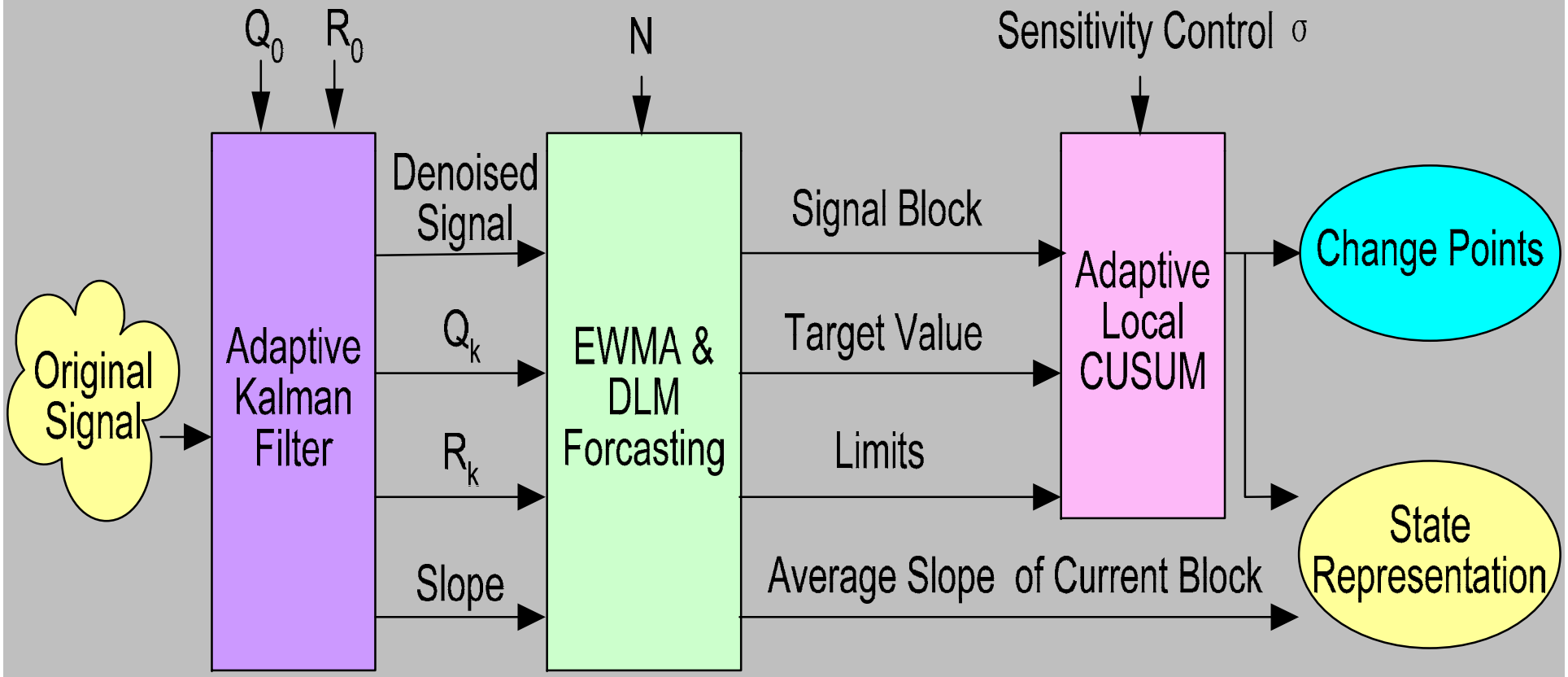
Measured signal value



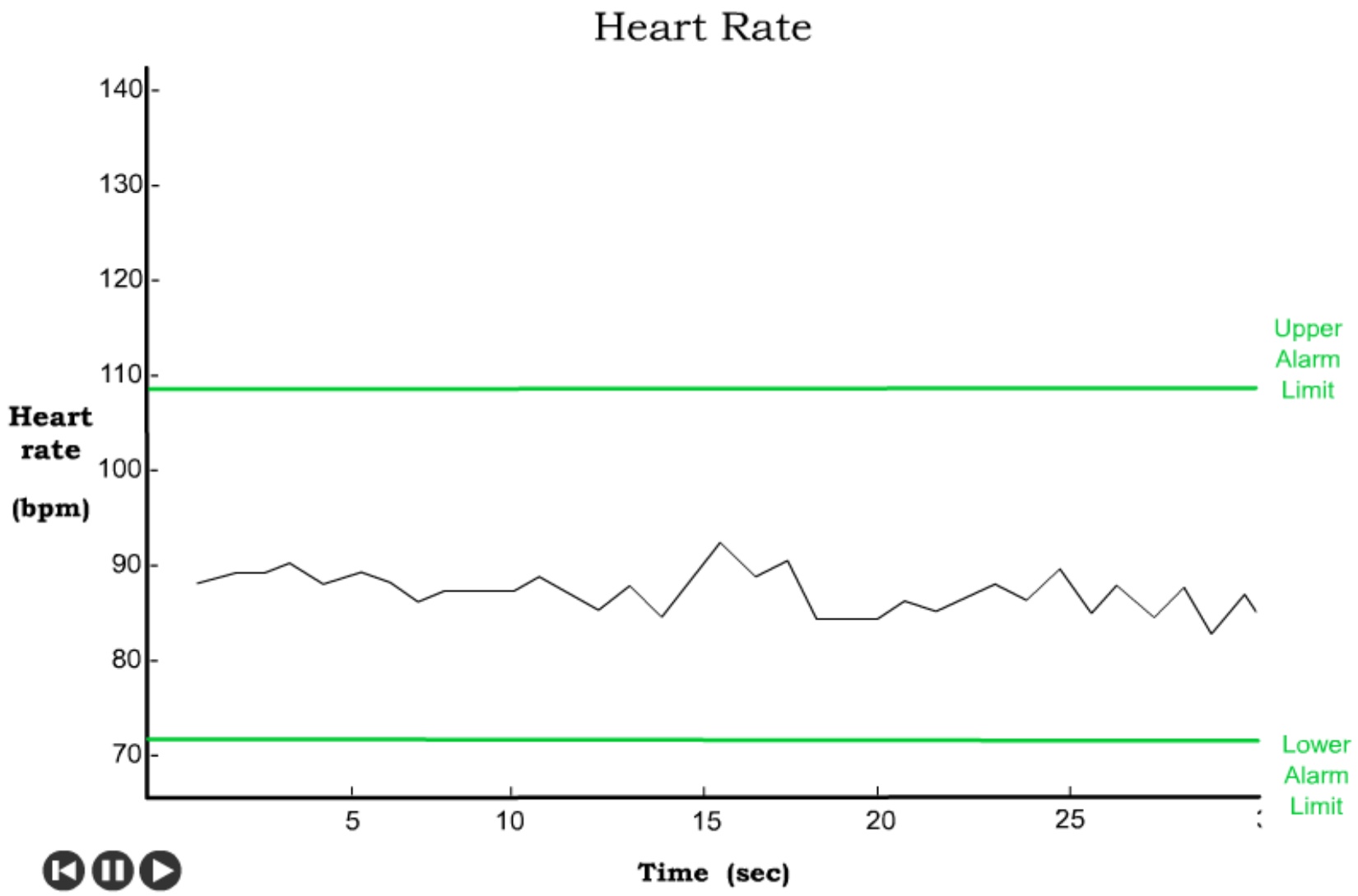
Signal noise

Inter patient and intraoperative variation

Adaptive feature extraction II

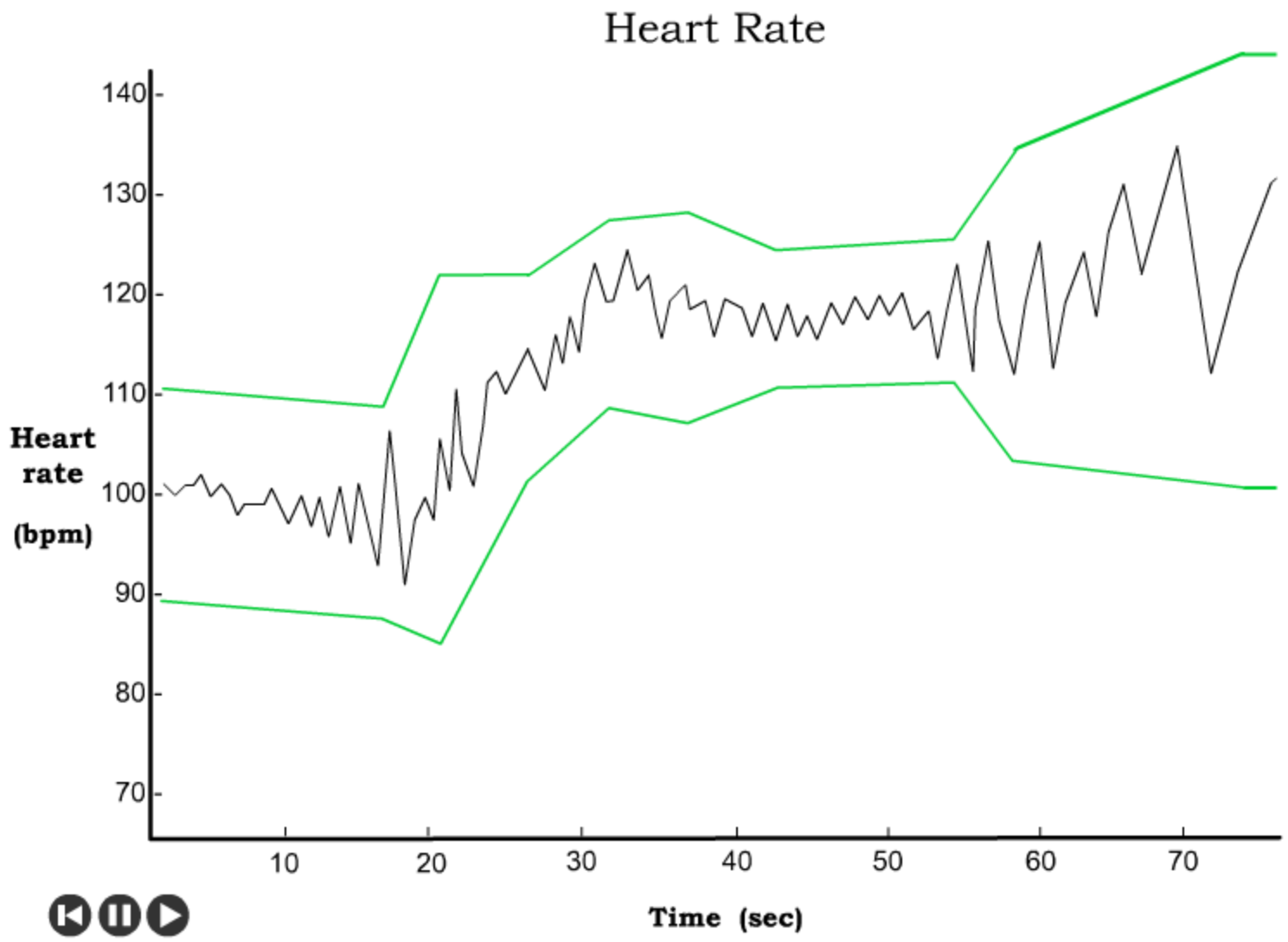


Limit Based Alarms



Get Flash Player

Adaptive Envelope



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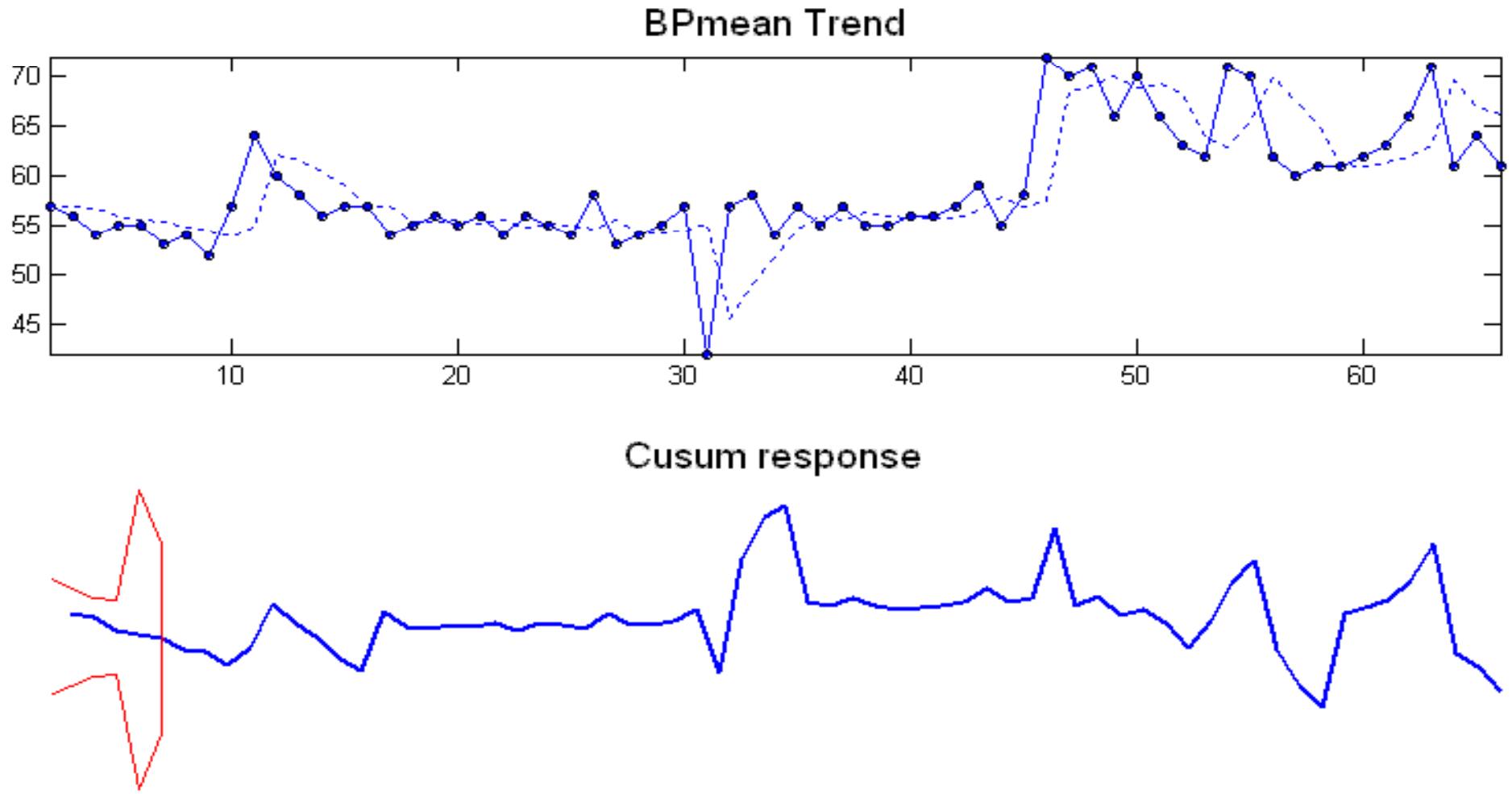
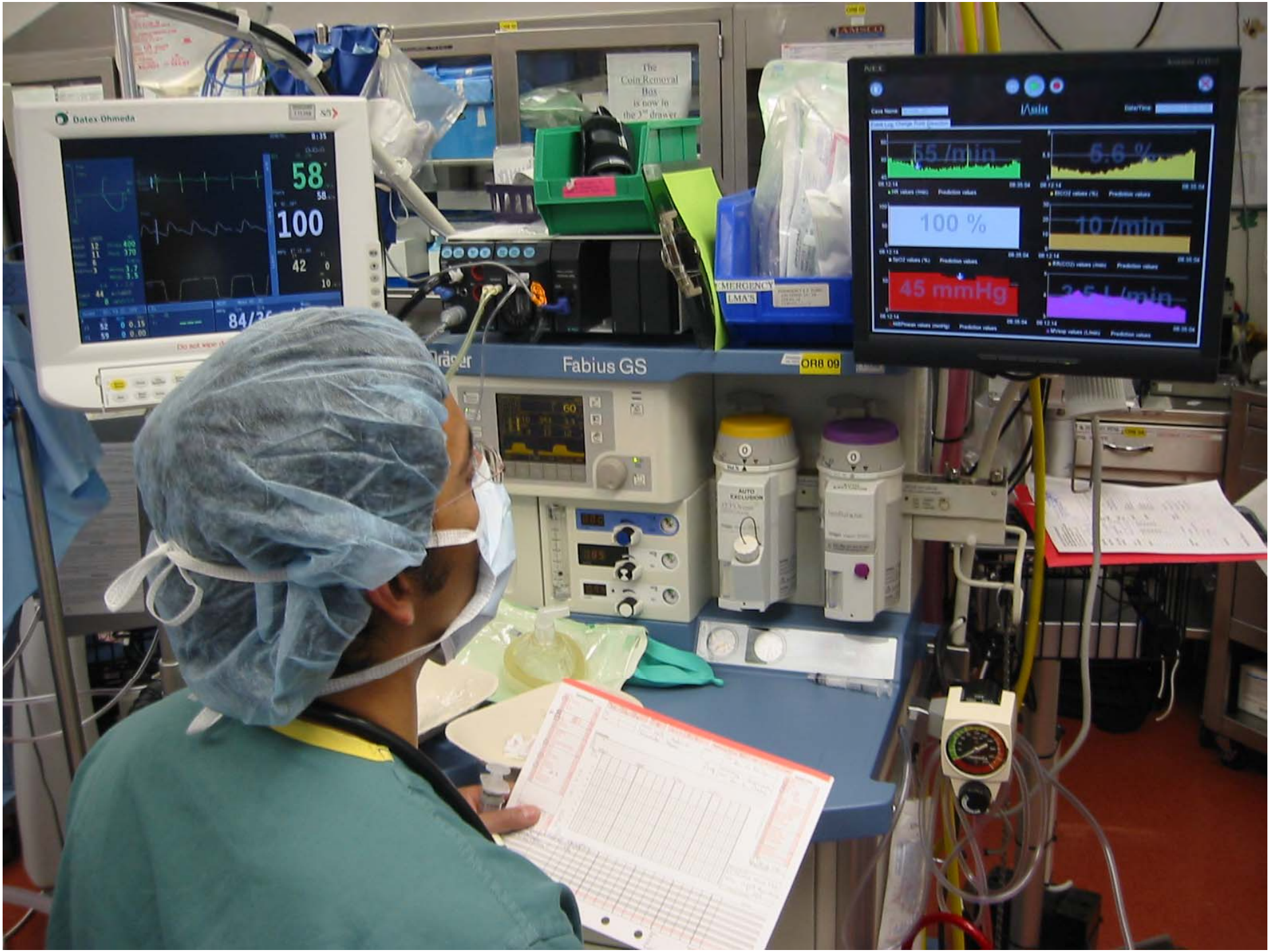
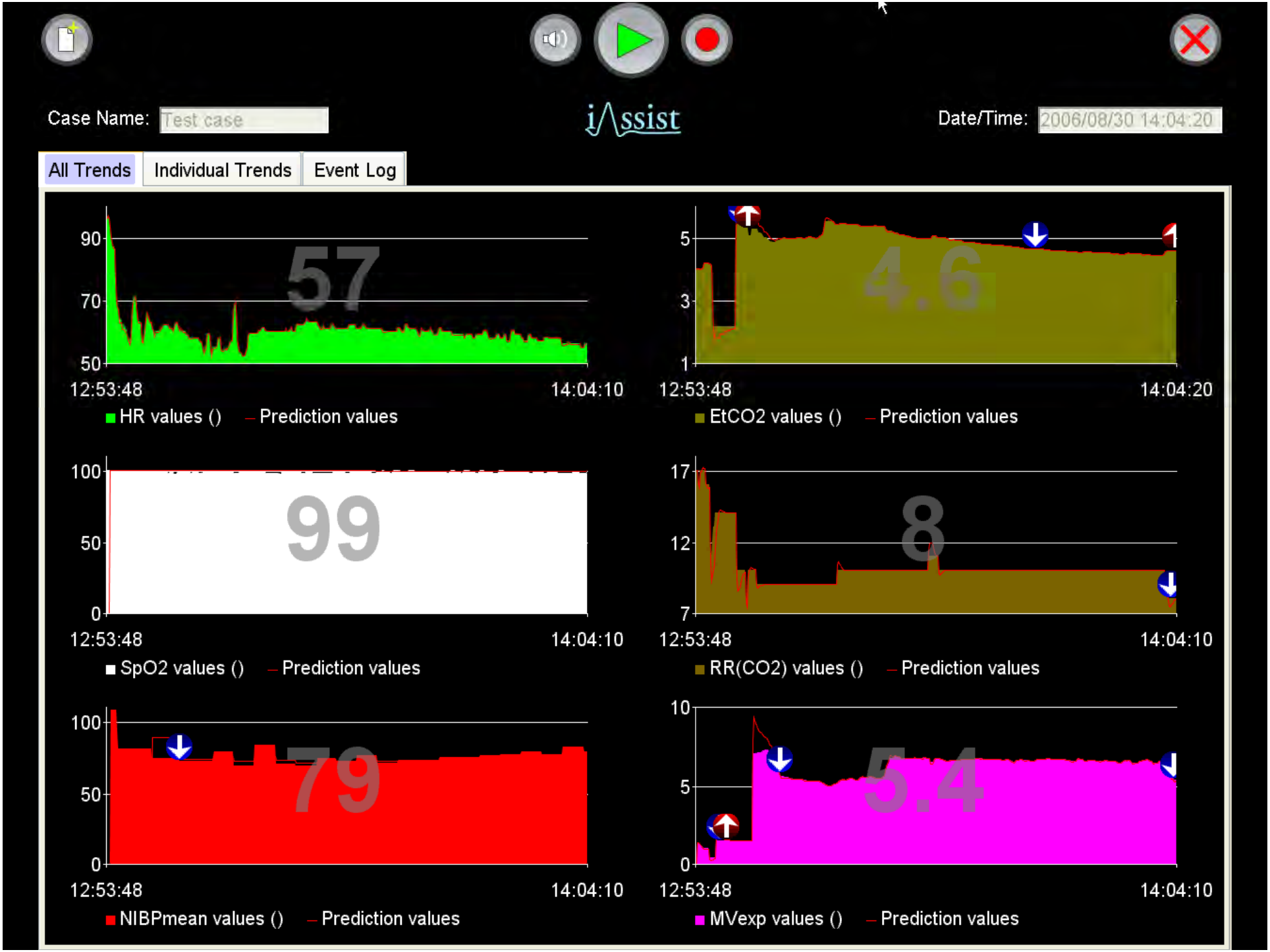
Change Point Detection - BP



Automated ‘change point’ detection

- Dependant on full history of the process
- Weighted towards more recent data
- Statistical features continuously updated
- Adaptable to individual patient
- Comparable to visual trend


Datex-Ohmeda
58
100
42
84/36
Fabius GS
OR8 09
55 /min
6.6 %
100 %
10 /min
45 mmHg
EMERGENCY
LMA's


Case Name: Test case
iAssist
Date/Time: 2006/08/30 14:04:20
All Trends
Individual Trends
Event Log
90
70
50
57
12:53:48
14:04:10
HR values ()
Prediction values
5
3
1
4.6
12:53:48
14:04:20
EtCO2 values ()
Prediction values
100
50
0
99
12:53:48
14:04:10
SpO2 values ()
Prediction values
17
12
7
8
12:53:48
14:04:10
RR(CO2) values ()
Prediction values
100
50
0
79
12:53:48
14:04:10
NIBPmean values ()
Prediction values
10
5
0
5.4
12:53:48
14:04:10
MVexp values ()
Prediction values

Results - Offline

Performance of iAssist compared to post hoc clinician review

	PPV	Events	Missed	Events/h
HR	0.92	297.00	33.00	4.36
NIBPmean	0.94	137.00	10.00	2.01
SpO2	0.98	50.00	0.00	0.73
ETCO2	0.74	249.00	20.00	3.66
MVexp	0.90	230.00	16.00	3.38
RR(CO2)	0.84	128.00	12.00	1.88
TOTAL	0.87	1091.00	91.00	16.02

PPV – positive predictive value

Ansermino, et al.. Anesthesia and Analgesia. 2009 ;108(3):873-80.

Results – On line

Classification of change points per hour of anaesthesia.

15 staff

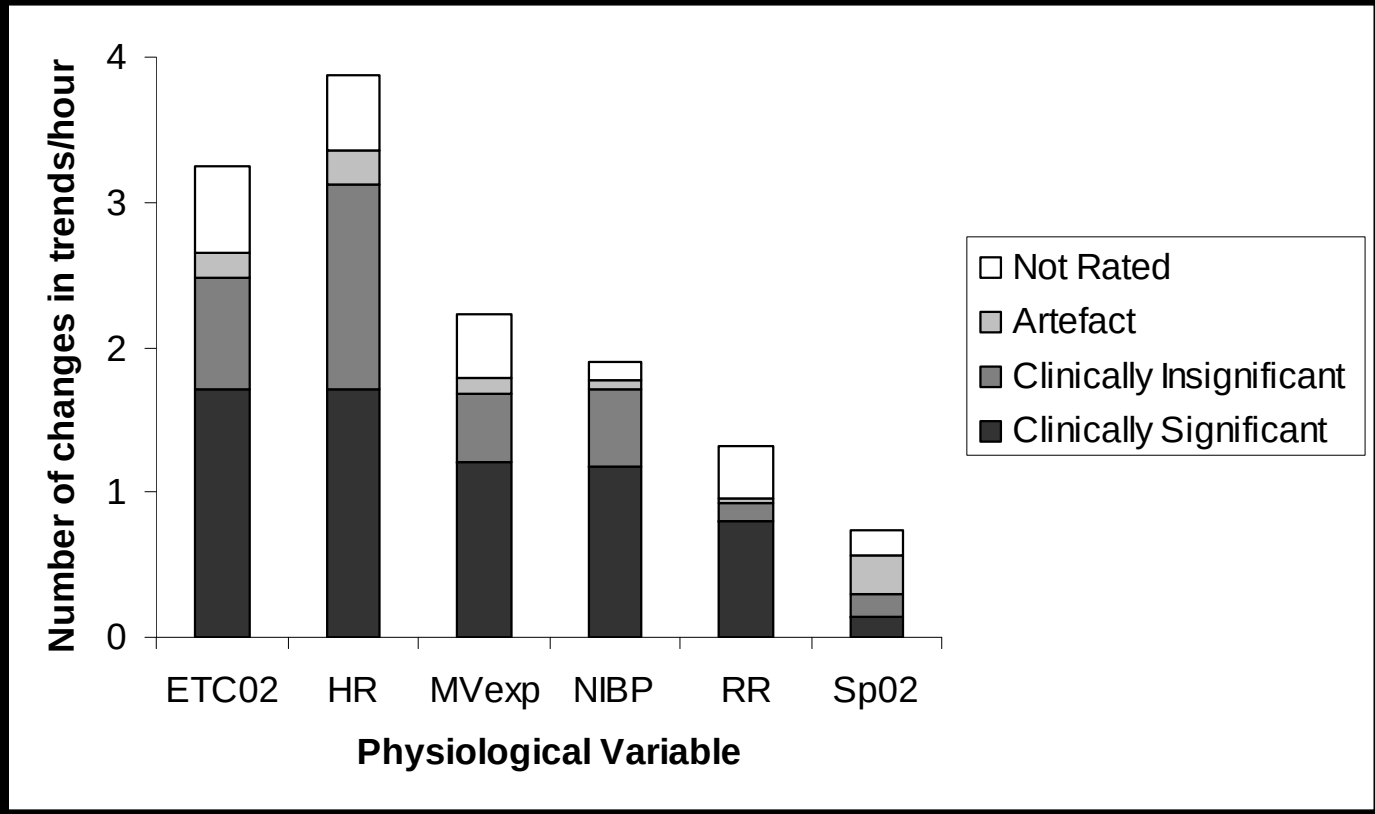
38 cases

103 min

22.8 /case

61% significant

7% artefacts



Dosani M, et al. BJA. 2009 ;102(5):686-91.

iKnow

Production rules for everyone!

Cognitive Bias | Information Overload

Types of Knowledge

- Explicit knowledge
  - Can be articulated into formal language, readily transmitted others, easily be processed by a computer.
- Tacit knowledge
  - Intangible factors embedded in individual experience, such as personal beliefs, and perspective (intuition). Hard to articulate with formal language (hard, but not impossible).

iKnow – knowledge authoring tool

Expert Knowledge

List of possible inputs:

Static representations

Heart rate
Blood pressure
Minute ventilation
Respiratory rate
Electrocautery activated

Dynamic representations

Heart rate increasing
Minute ventilation decreasing
Mean blood pressure 10 min
Heart rate variability
Systolic pressure variation

Rules:

If ... then

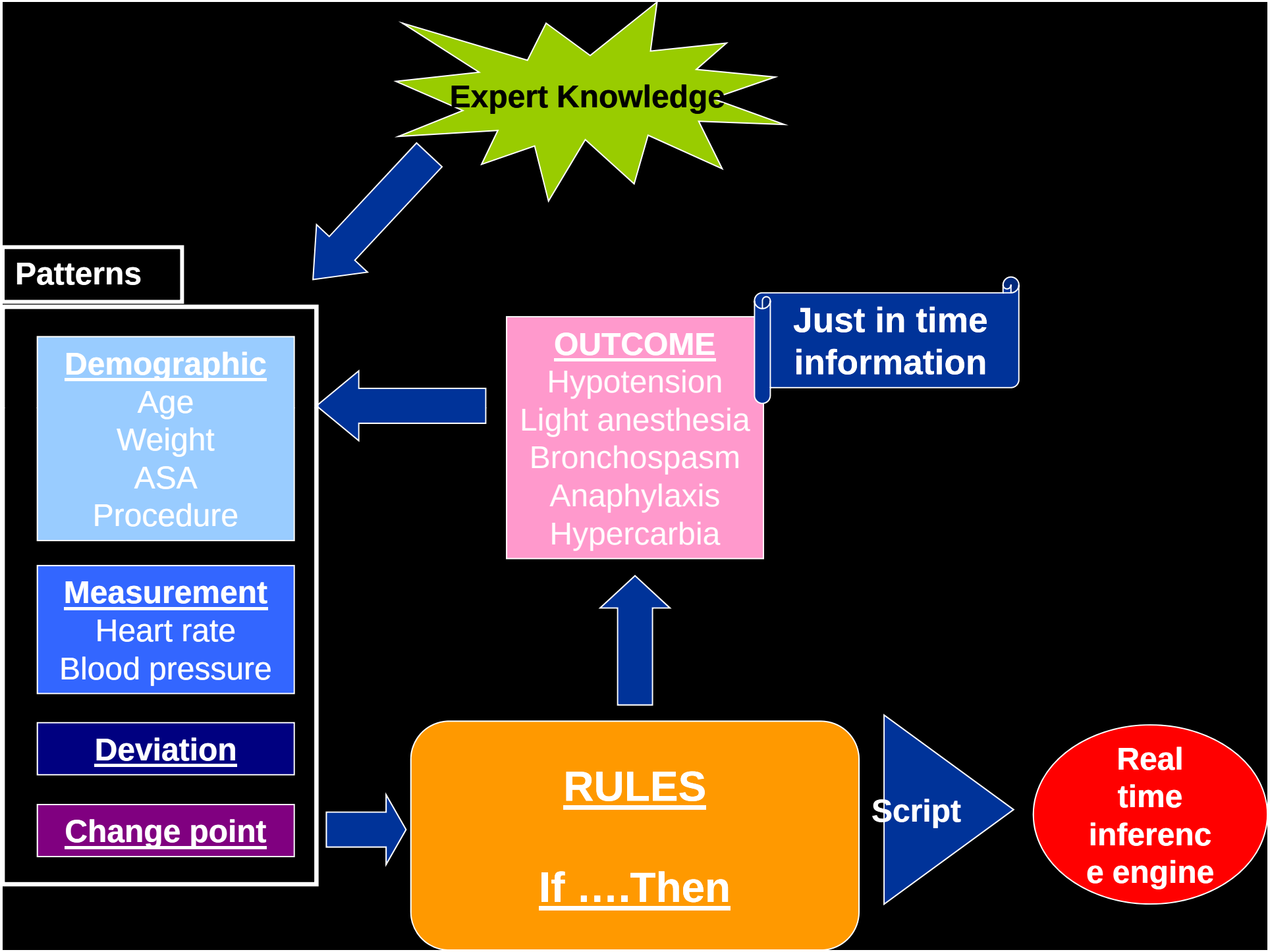
and ... or
greater than... less than

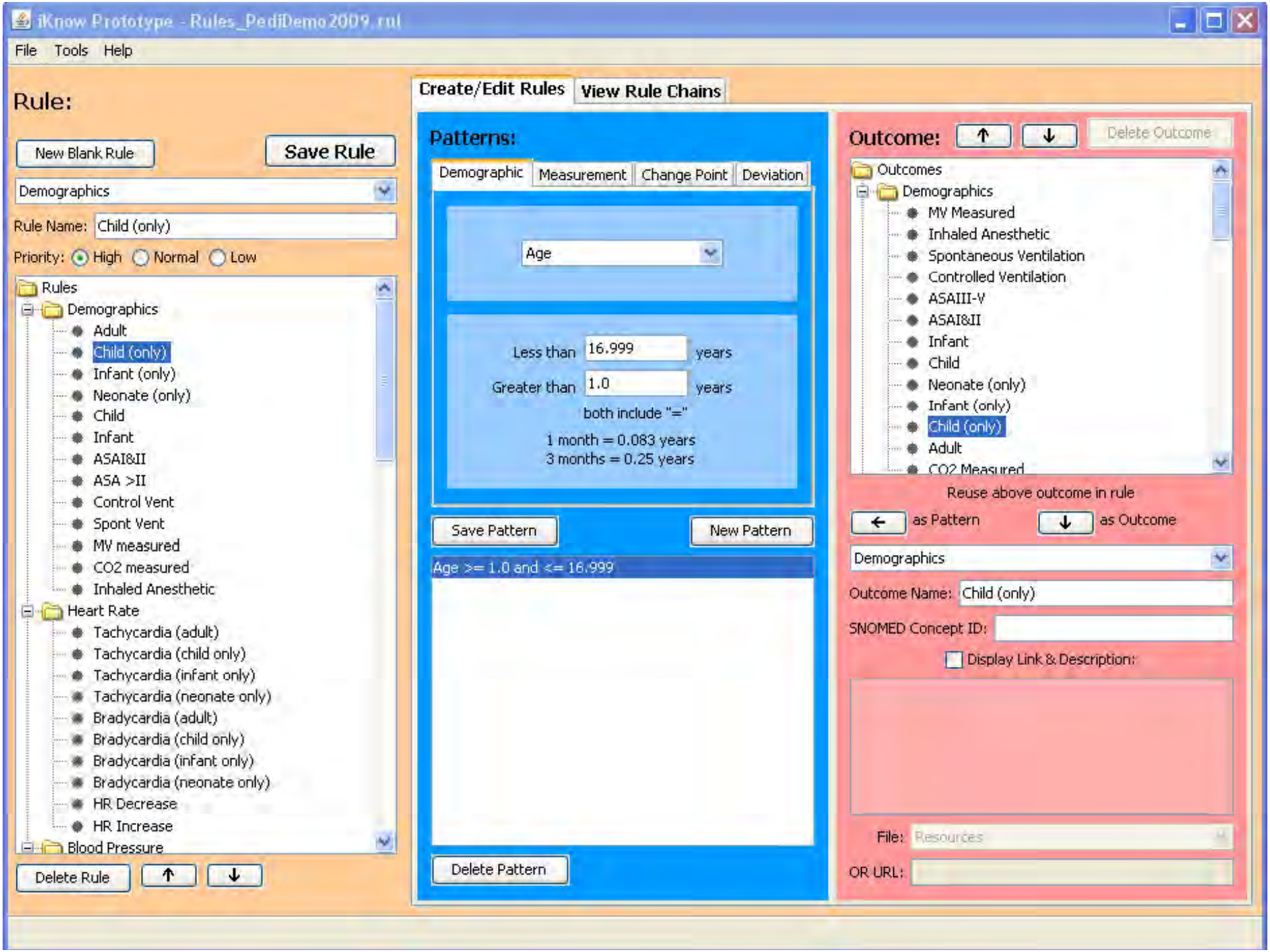
List of possible outputs:

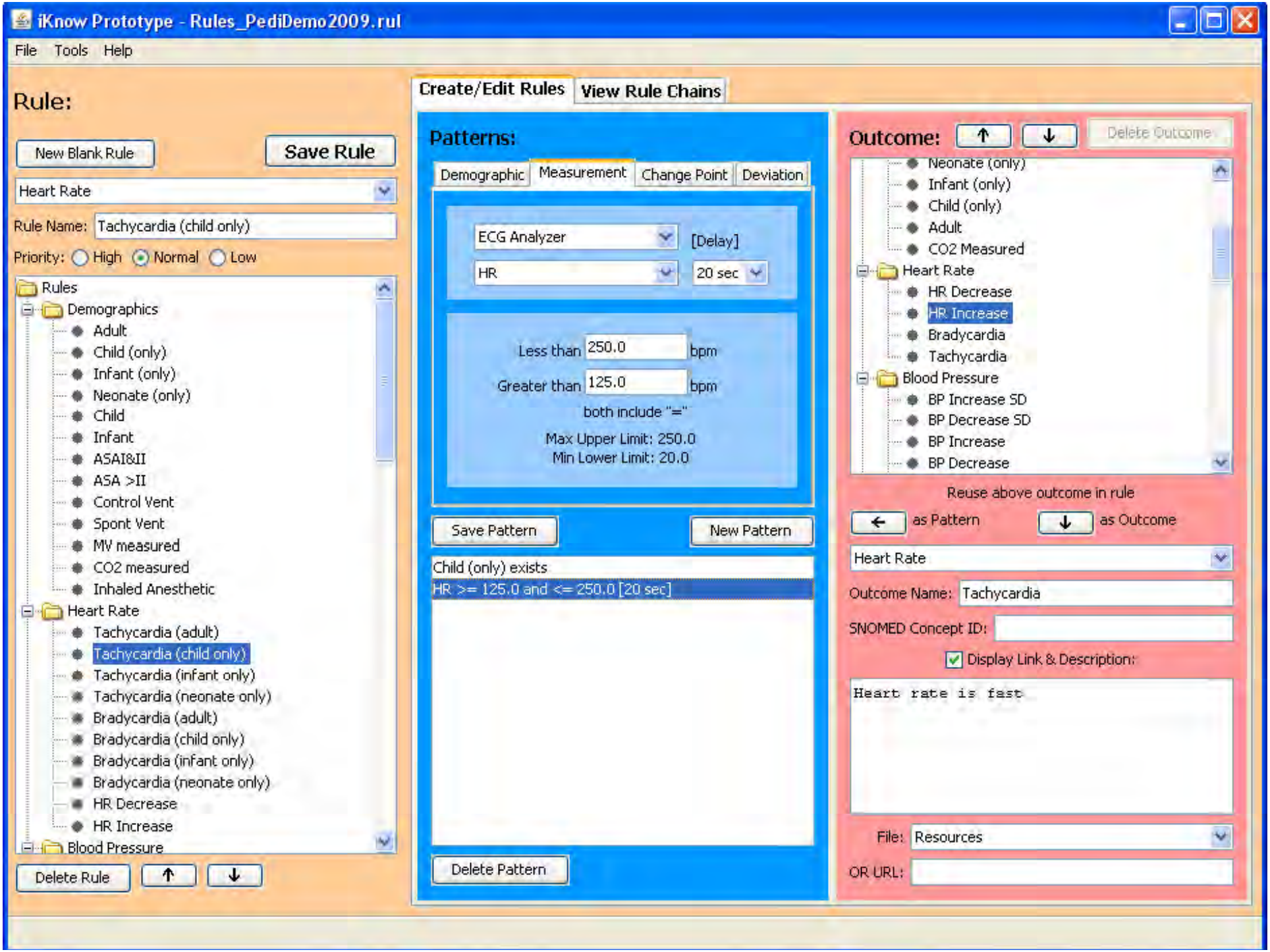
Hypotension
Light anesthesia
Bronchospasm
Circuit leak
Circuit disconnect
Anesthetic overdose
Myocardial ischemia
Hyperthermia
Pulmonary embolism
Main stem intubation
Anaphylaxis

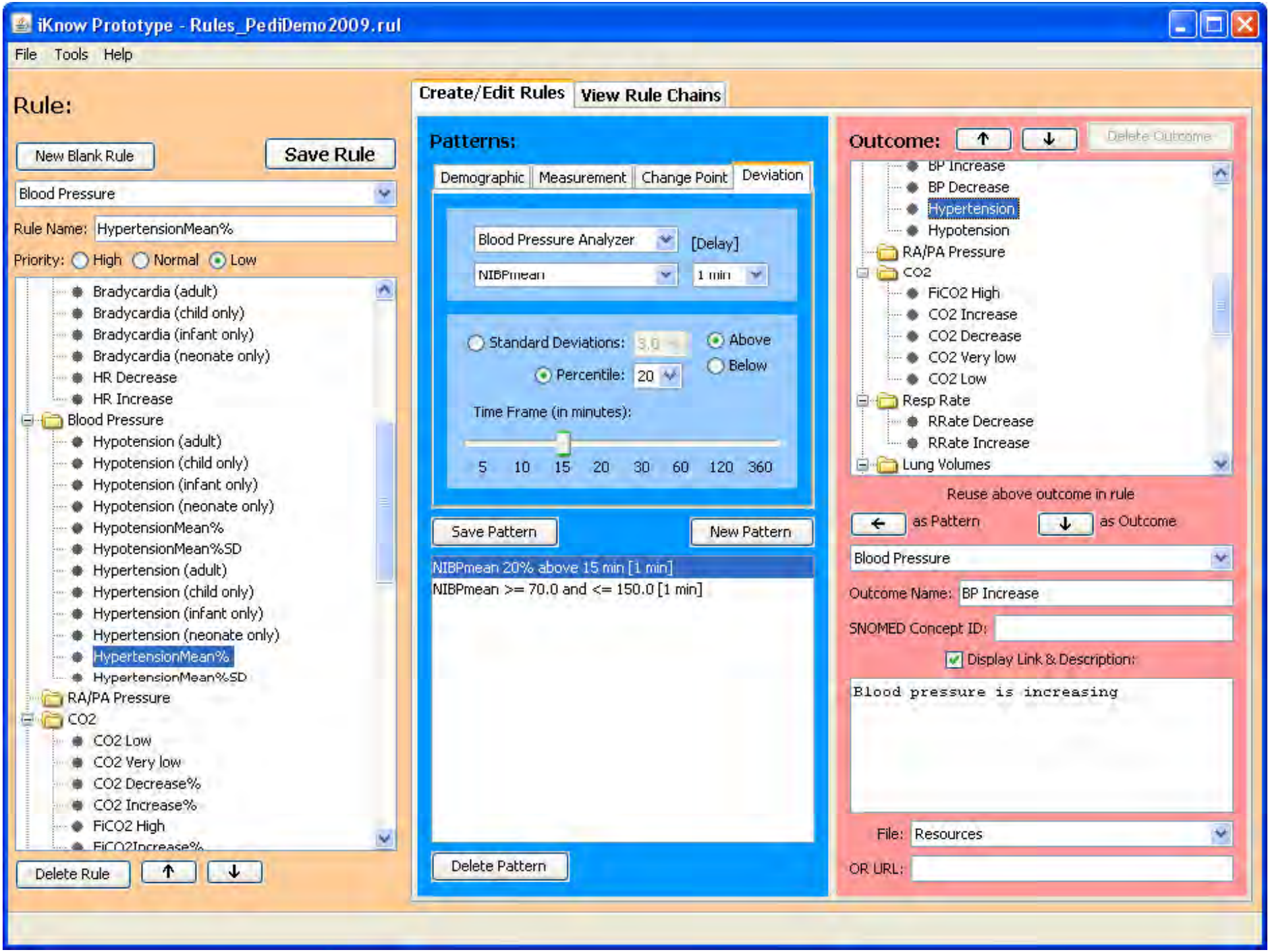
ISO/ IEEE 11073

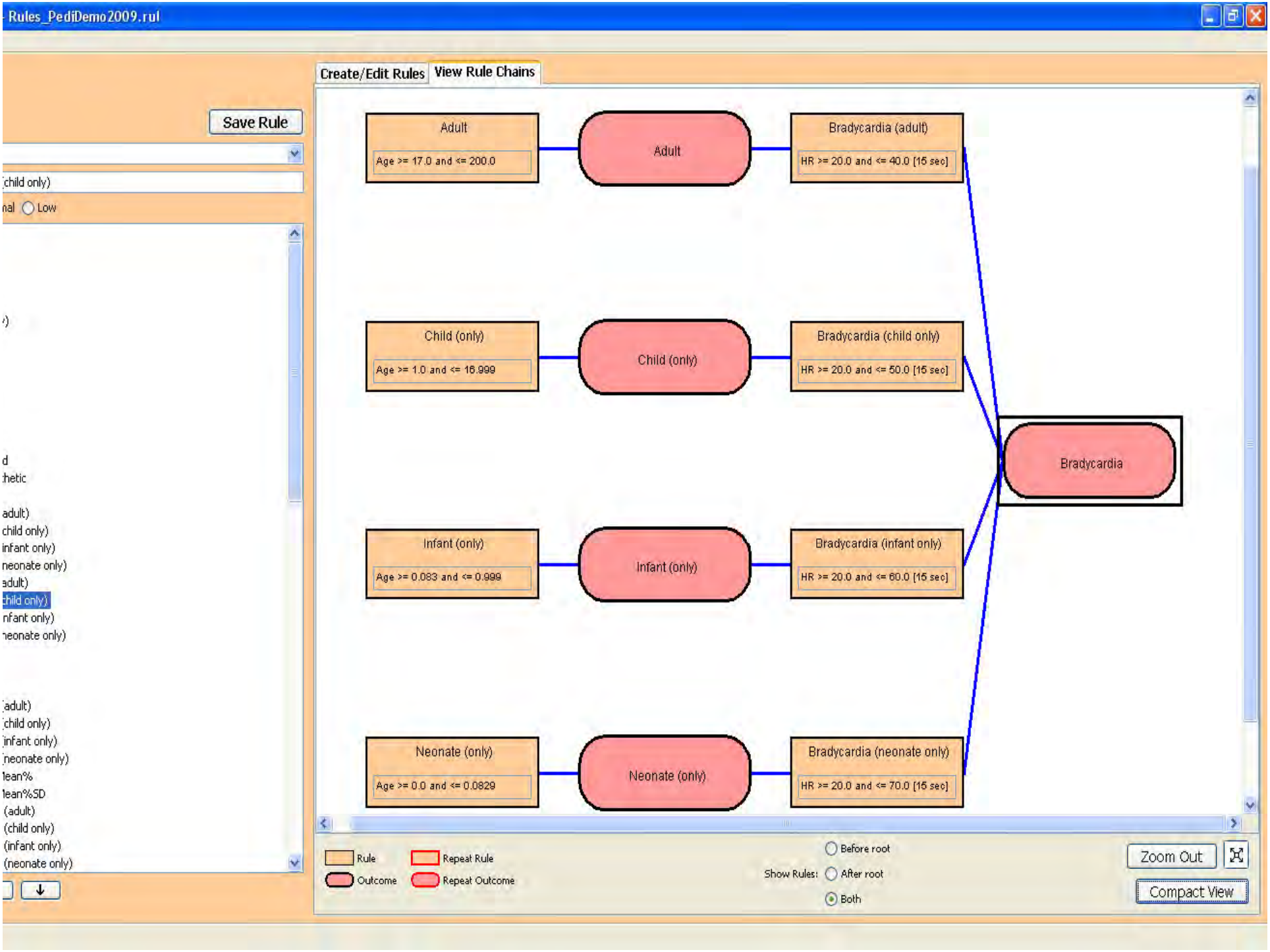
Snowmed

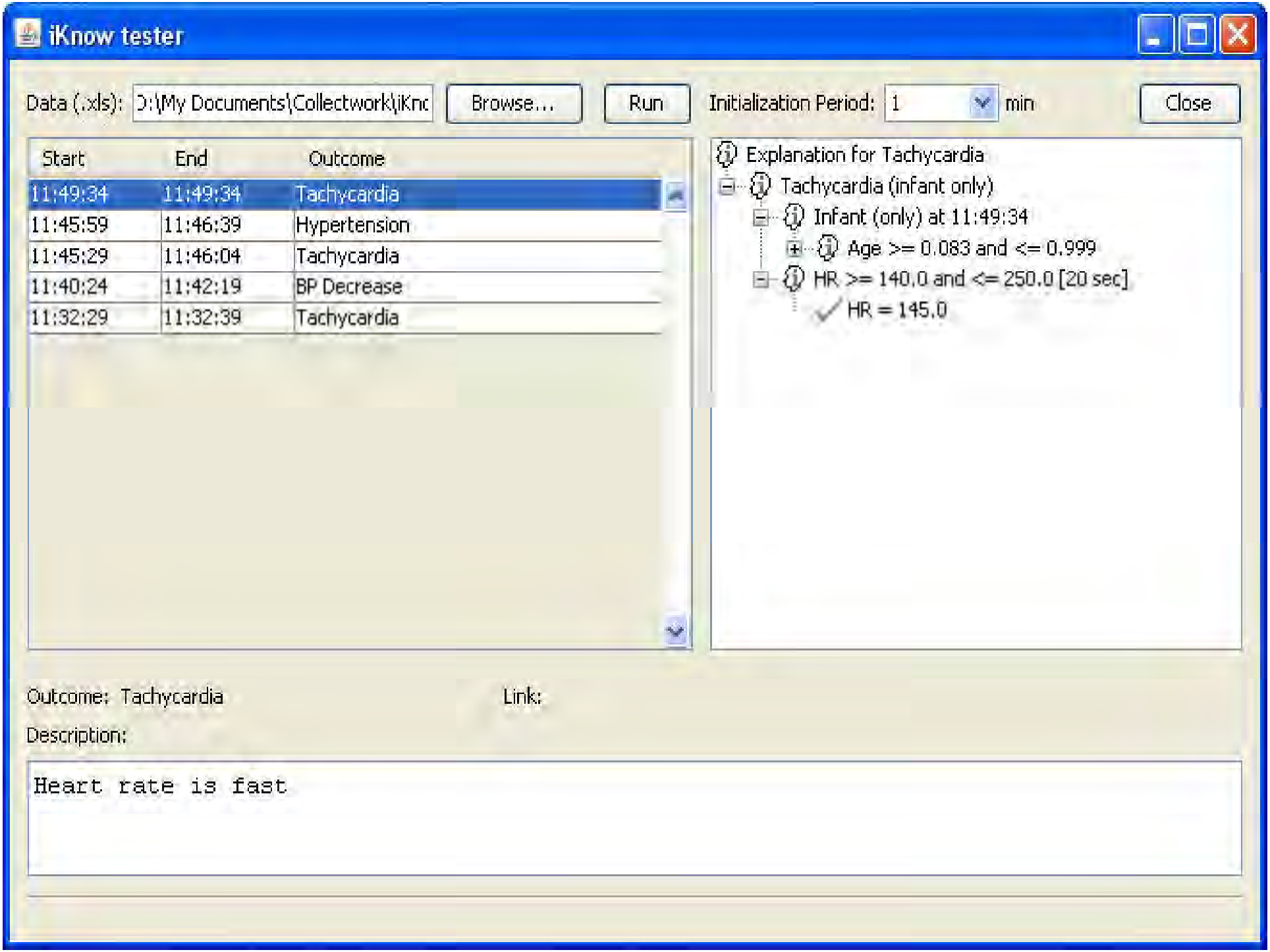

Expert Knowledge
Patterns
Demographic
Age
Weight
ASA
Procedure
Measurement
Heart rate
Blood pressure
Deviation
Change point
OUTCOME
Hypotension
Light anesthesia
Bronchospasm
Anaphylaxis
Hypercarbia
Just in time information
RULES
If ….Then
Script
Real time inferenc e engine


iKnow Prototype - Rules_PediDemo2009.rul
File
Tools
Help
Rule:
New Blank Rule
Save Rule
Demographics
Rule Name: Child (only)
Priority: High Normal Low
Rules
Demographics
Adult
Child (only)
Infant (only)
Neonate (only)
Child
Infant
ASAI&II
ASA >II
Control Vent
Spont Vent
MV measured
CO2 measured
Inhaled Anesthetic
Heart Rate
Tachycardia (adult)
Tachycardia (child only)
Tachycardia (infant only)
Tachycardia (neonate only)
Bradycardia (adult)
Bradycardia (child only)
Bradycardia (infant only)
Bradycardia (neonate only)
HR Decrease
HR Increase
Blood Pressure
Delete Rule
Create/Edit Rules
View Rule Chains
Patterns:
Demographic
Measurement
Change Point
Deviation
Age
Less than 16.999 years
Greater than 1.0 years
both include "="
1 month = 0.083 years
3 months = 0.25 years
Save Pattern
New Pattern
Age >= 1.0 and <= 16.999
Delete Pattern
Outcome:
Delete Outcome
Outcomes
Demographics
MV Measured
Inhaled Anesthetic
Spontaneous Ventilation
Controlled Ventilation
ASAIII-V
ASAI&II
Infant
Child
Neonate (only)
Infant (only)
Child (only)
Adult
CO2 Measured
Reuse above outcome in rule
as Pattern
as Outcome
Demographics
Outcome Name: Child (only)
SNOMED Concept ID:
Display Link & Description:
File: Resources
OR URL:


iKnow Prototype - Rules_PediDemo2009.rul
File
Tools
Help
Rule:
New Blank Rule
Save Rule
Heart Rate
Rule Name: Tachycardia (child only)
Priority: High Normal Low
Rules
Demographics
Adult
Child (only)
Infant (only)
Neonate (only)
Child
Infant
ASAI&II
ASA >II
Control Vent
Spont Vent
MV measured
CO2 measured
Inhaled Anesthetic
Heart Rate
Tachycardia (adult)
Tachycardia (child only)
Tachycardia (infant only)
Tachycardia (neonate only)
Bradycardia (adult)
Bradycardia (child only)
Bradycardia (infant only)
Bradycardia (neonate only)
HR Decrease
HR Increase
Blood Pressure
Delete Rule
Create/Edit Rules
View Rule Chains
Patterns:
Demographic
Measurement
Change Point
Deviation
ECG Analyzer
[Delay]
HR
20 sec
Less than 250.0 bpm
Greater than 125.0 bpm
both include "="
Max Upper Limit: 250.0
Min Lower Limit: 20.0
Save Pattern
New Pattern
Child (only) exists
HR >= 125.0 and <= 250.0 [20 sec]
Delete Pattern
Outcome:
Delete Outcome
Neonate (only)
Infant (only)
Child (only)
Adult
CO2 Measured
Heart Rate
HR Decrease
HR Increase
Bradycardia
Tachycardia
Blood Pressure
BP Increase SD
BP Decrease SD
BP Increase
BP Decrease
Reuse above outcome in rule
as Pattern
as Outcome
Heart Rate
Outcome Name: Tachycardia
SNOMED Concept ID:
Display Link & Description:
Heart rate is fast
File: Resources
OR URL:


iKnow Prototype - Rules_PediDemo2009.rul
File Tools Help
Rule:
New Blank Rule
Save Rule
Blood Pressure
Rule Name: HypertensionMean%
Priority: High Normal Low
Bradycardia (adult)
Bradycardia (child only)
Bradycardia (infant only)
Bradycardia (neonate only)
HR Decrease
HR Increase
Blood Pressure
Hypotension (adult)
Hypotension (child only)
Hypotension (infant only)
Hypotension (neonate only)
HypotensionMean%
HypotensionMean%SD
Hypertension (adult)
Hypertension (child only)
Hypertension (infant only)
Hypertension (neonate only)
HypertensionMean%
HypertensionMean%SD
RA/PA Pressure
CO2
CO2 Low
CO2 Very low
CO2 Decrease%
CO2 Increase%
FiCO2 High
FiCO2Increase%
Delete Rule
Create/Edit Rules
View Rule Chains
Patterns:
Demographic
Measurement
Change Point
Deviation
Blood Pressure Analyzer
[Delay]
NIBPmean
1 min
Standard Deviations: 3.0
Above
Percentile: 20
Below
Time Frame (in minutes):
5 10 15 20 30 60 120 360
Save Pattern
New Pattern
NIBPmean 20% above 15 min [1 min]
NIBPmean >= 70.0 and <= 150.0 [1 min]
Delete Pattern
Outcome:
Delete Outcome
BP Increase
BP Decrease
Hypertension
Hypotension
RA/PA Pressure
CO2
FiCO2 High
CO2 Increase
CO2 Decrease
CO2 Very low
CO2 Low
Resp Rate
RRate Decrease
RRate Increase
Lung Volumes
Reuse above outcome in rule
as Pattern
as Outcome
Blood Pressure
Outcome Name: BP Increase
SNOMED Concept ID:
Display Link & Description:
Blood pressure is increasing
File: Resources
OR URL:


Rules_PediDemo2009.rul
Save Rule
Create/Edit Rules
View Rule Chains
Adult
Age >= 17.0 and <= 200.0
Adult
Bradycardia (adult)
HR >= 20.0 and <= 40.0 [15 sec]
Child (only)
Age >= 1.0 and <= 16.999
Child (only)
Bradycardia (child only)
HR >= 20.0 and <= 50.0 [15 sec]
Infant (only)
Age >= 0.083 and <= 0.999
Infant (only)
Bradycardia (infant only)
HR >= 20.0 and <= 60.0 [15 sec]
Neonate (only)
Age >= 0.0 and <= 0.0829
Neonate (only)
Bradycardia (neonate only)
HR >= 20.0 and <= 70.0 [15 sec]
Bradycardia
Rule
Repeat Rule
Outcome
Repeat Outcome
Show Rules:
Before root
After root
Both
Zoom Out
Compact View


iKnow tester
Data (.xls):
D:\My Documents\Collectwork\iKnc
Browse...
Run
Initialization Period:
1
min
Close
Start
End
Outcome
11:49:34
11:49:34
Tachycardia
11:45:59
11:46:39
Hypertension
11:45:29
11:46:04
Tachycardia
11:40:24
11:42:19
BP Decrease
11:32:29
11:32:39
Tachycardia
Explanation for Tachycardia
Tachycardia (infant only)
Infant (only) at 11:49:34
Age >= 0.083 and <= 0.999
HR >= 140.0 and <= 250.0 [20 sec]
HR = 145.0
Outcome: Tachycardia
Link:
Description:
Heart rate is fast

http://engineering4medicine.chii.ubc.ca/iknow/

iKnow

iKnow Information

Home
Model
FAQ
Download

Help Files

- Purpose
- Quick Start
- Rule Components
- Panel Descriptions
- Walkthrough
- Input and Output
- Menu items

Contact

Knowledge Authoring Tool

iKnow is a tool for building a knowledge base for physiological monitoring. Expert knowledge about physiological monitoring, such as is used in anesthesia or the intensive care unit, is encoded into a set of rules. These rules are used in real time by the inference engine of an expert system. iKnow is designed to be easy to use and avoid the need for a knowledge engineer for rule creation. The rules are run in real time against inputs from clinical monitoring devices.

iKnow can create a custom list of rules representing the individual clinician's knowledge or developed collaboratively by an institution or professional organization to standardize group knowledge.

The software generates programming code in a rule-based expert system language called JBoss Rules. The set of rules are then run, in real time at the patient's bedside, against data generated by physiological monitors. Included within the iKnow program is a testing sub-application which allows a user to test the rules output against data in an Excel file. The data in this Excel file can be edited to force the rules to fire.

Automation is the ultimate decision support !

Thanks for listening….

Mark Ansermino
mansermino@cw.bc.ca